The Frontal Plane Vectorcardiogram in Old Inferior Myocardial Infarction

Criteria for Diagnosis and Electrocardiographic Correlation

By Eliot Young, M.D., and Conger Williams, M.D.

SUMMARY

The early part of the frontal plane QRS loop (Frank lead system) was analyzed in 100 consecutive patients with an old inferior myocardial infarction. In order to be included in this study, all cases had to fulfill, at some time, Myers' classical ECG criteria for the diagnosis. The vectorcardiogram was made months to years after the patient's original acute episode.

Several scalar and planar parameters, pertaining to these frontal plane early QRS vectors, were analyzed. As a result of this analysis and in order to prevent overlap with values found in 315 normal control subjects, VCG criteria, based on the interrelationships of several of these parameters, were proposed for the diagnosis of old inferior myocardial infarction. Pitfalls in the use of only scalar or planar analyses were pointed out.

In 90 of the 100 cases the diagnosis was made on the basis of the proposed VCG criteria. However, the ECG made at the same time fulfilled Myers' or Goldberger's classical criteria in only 42 of the 100 cases. All cases diagnosed from the ECG were also diagnosed from the VCG.

Additional Indexing Words:
Myers' ECG criteria Early QRS forces Total pattern analysis
Direction of inscription Normal variant Scalar and planar measurements

It is commonly appreciated\(^5\) that there is need to supplement the classical electrocardiographic Q-wave criteria\(^4,6\) for the diagnosis of old inferior myocardial infarction. During the acute phase of infarction the diagnosis is usually easily made because the QRS is generally associated with characteristic RS-T segment and T-wave changes. However, after the process has healed, these latter ECG abnormalities may not be present and residual QRS changes are often minimal or absent.

Recently published reports\(^7,8,10,14\) have suggested that vectorcardiography may be more helpful than electrocardiography in detecting QRS changes of inferior myocardial infarction. Nonetheless, the authors in all of these studies have found cases that could not be diagnosed either by vectorcardiography (VCG) or electrocardiography (ECG).

Extensive experience has indicated to us that the VCG criteria proposed in recent studies\(^7-10\) significantly overlapped values found in normal controls as well as in other types of cardiac disease. Gunnar and associates\(^11\) applying some of these criteria to findings at autopsy, arrived at a similar conclusion. Simonson and associates\(^4\) in a cooperative study stated: "The results show that, in regard to myocardial infarction, VCG and ECG, when used as independent diagnostic tools, have the same diagnostic value for correct recognition, while the percentage of false positive diagnoses of MI is higher with the VCG."

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They pointed out, however, “that the information contained in planar loop projections is not sufficiently utilized for interpretations.” They also emphasized, “the desirability of quantitative VCG analysis.”

In view of the continuing and unsettled controversy as to the relative value of vectorcardiography versus electrocardiography for the diagnosis of inferior infarction, a reassessment of the VCG criteria currently in use was undertaken.

This study will present detailed scalar and planar analyses of the early part of the QRS loop in the frontal plane VCG of patients with old inferior myocardial infarction. Electrocardiographic correlation will be made, and the value of this technique in comparison with vectorcardiography assessed.

**Methods**

VCGs, in all three planar projections, were recorded in the supine position by the Frank lead reference system. Electrodes were placed at the fourth interspace as suggested by Langner and associates for the supine position. A standard 12-lead ECG was obtained when the patient was brought to the laboratory for the VCG.

The frontal plane VCGs were analyzed in 100 consecutive cases of old inferior myocardial infarction. One case among those originally selected was excluded because bundle branch block was also evident.

The original acute illness occurred months to years prior to the time the VCG was recorded. Most patients had no apparent significant cause for heart disease other than coronary atherosclerosis. However, a few did have moderate hypertension recorded at some time.

Vectorcardiographic studies in inferior infarctions have been based, for the most part, on the presence in the ECG of obviously altered Q waves of lead aVF that fulfilled the usual classical ECG criteria. In addition, one report also had a large percentage of cases proven at autopsy. Nonetheless, this same study did include some instances with only RS-T segment changes in the ECG. Thus, it is possible that all of these authors excluded many cases that did not show diagnostic QaVF waves but did reveal abnormal early superior forces in the frontal plane VCG.

Abramson wrote a paper based on 70 cases; in 50, classical QaVF wave changes showed and in 20, only RS-T segment abnormalities. However, the vectorcardiographic criteria he proposed for the diagnosis of inferior infarction are used less often than those in the three papers noted in the preceding paragraph. Moreover, in many of his cases VCGs were done only at the time of the acute episode.

The vectorcardiographic study herein reported was designed to minimize the bias of selecting only those patients with classical, obvious QaVF wave alterations. Thus the 100 inferior infarctions to be discussed fulfilled at some time one of Myers and associates' three vectorcardiographic criteria pertaining to lead aVF: (1) classical obvious Q wave changes, that is (a) QR complex of 0.5 mv or more, with a Q wave measuring 0.03 sec or more from onset to nadir and a Q/R ratio over 25% or (b) QR complex meeting some but not all of the requirements in “1a” but associated with a Q wave measuring 0.04 sec or more from onset to nadir; (2) borderline less obvious Q-wave alterations meeting some but not all of the requirements listed under “1a” provided that a previous tracing was perfectly normal; and (3) classical RS-T segment changes at the time of the acute episode even if the Q wave appeared entirely normal. However, as will be shown, many of the ECGs in all three groups recorded after the acute episode and at the time of the VCG were nondiagnostic. Thus, the opportunity arose of testing the value of vectorcardiology when electrocardiography either was or was not helpful.

Myers' criteria were chosen because they have become increasingly favored and are based on the largest number of autopsy-proven cases.

According to most commonly used vectorcardiographic and electrocardiographic criteria, about 20% of the 100 inferior myocardial infarctions to be discussed were apparently associated with some infarction in other "electrically manifest" areas. Nevertheless, with the exceptions to be noted, the characteristic frontal plane features of the early part of the QRS loop in "pure" inferior infarction were retained. Moreover, we have included these cases in order to conform with the trend in the electrocardiographic and vectorcardiographic literature.

As a basis of comparison, the Frank frontal plane VCGs of 315 normal adult subjects were analyzed (table 1). All patients were carefully questioned and examined for possible causes of heart disease. A standard 12-lead ECG was made on all and chest x-rays were taken on most. Aside from minor exceptions to be noted, early QRS forces were generally similar in the older and younger subjects. Thus, it is doubtful that undetected coronary atherosclerotic heart disease significantly biased the results of this study.
Table 1

<table>
<thead>
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<th>Age and Sex of 315 Normal Control Subjects</th>
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<tr>
<td></td>
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<tr>
<td>Age (yr)</td>
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VCGs, for the most part, were recorded by a Hart Electronics instrument (model PV-3). A few were done by a Sanborn VCG system. VCG amplifiers were set at a high frequency response of 200 to 300 Hz and a low frequency response of 0.2 Hz. Since extreme range may introduce artifact, we chose to record all our VCGs in the above frequency range. Emphasis is placed on the high frequency response of the VCG amplifiers. A frequency response of 100 Hz or less (generally the upper frequency response of conventional ECG amplifiers) may degrade the planar phase relationships as well as decrease the magnitude of the deflections of the QRS loop herein described.

A Polaroid camera with image to object ratio of 0.9:1.0 was used. Deflections (mv-equivalents) were measured from the Polaroid prints. Except for figure 7, all loops herein illustrated (figs. 1 to 11) are exact size tracings of these photographs and thus closely approximate the actual deviations recorded by the oscilloscope.

Generally, VCGs were recorded with amplifier sensitivity set so that deflections of 3.5 to 7.5 cm equaled 1 mv of signal input. However, to visualize clearly the magnitude of the deflection as well as the duration of QRS vectors about the null point, some loops were recorded so that a 15-cm or more deflection equaled 1 mv.

Nomenclature used in this report is in accordance with the recent recommendations of the Committee on Electrocardiography, American Heart Association.20 Millivolts of right or left deviation were measured from a specific vector perpendicularly to the Y (longitudinal) axis line bisecting the null point. Similarly, millivolts of superior or inferior deviation were measured from a specific vector perpendicularly to the X (transverse) axis line bisecting the null point. In contrast, the frontal plane maximal QRS vector was the point of greatest distance from any portion of the QRS loop measured directly to the null point.

Background Material

The literature dealing with VCG criteria for diagnosing inferior myocardial infarction is mostly concerned with altered early superior QRS forces in the frontal plane. These vectors are almost always inscribed in a clockwise direction.7–9, 21, 22 In addition, important diagnostic information may be obtained by the quantitative analyses of the superior deviation, magnitude of the right-to-left sweep, and duration of these early superior QRS forces.21, 23 The ratio of the superior deviation of early vectors to the most inferior deviation of the entire QRS was also found to be diagnostically helpful.21 These criteria applied even when very initial forces were inferior.21 As a further aid in diagnosis, it was pointed out that some of the characteristics of inferior infarction as well as normal early superior frontal plane QRS vectors were related to the planar location (α° or F°) of the maximal QRS vector and direction of inscription (rotation) of the loop.21, 23

Hoffman and co-workers,7 using the Frank reference system, found that the early superior QRS vectors in the frontal plane were inscribed in a clockwise direction in 76 of 78 past inferior infarctions. Sixty-six of these 76 cases displayed early superior forces having a duration of 0.025 sec or more. They stated that "this measurement was the single most reliable indication of inferior infarction." They also analyzed the magnitude of the leftward deviation of these superior forces. Although no normal control measurements were given, the leftward deviation measured 0.3 mv or more in 63 of their 76 cases of infarction. Six of the 10 patients with early superior forces less than 0.025 sec displayed leftward deviation of these vectors of 0.3 mv or more. Nine of 13 patients with leftward deviation of early superior forces of less than 0.3 mv had a duration of 0.025 sec or more of early superior vectors. However, four of the 76 patients had low values for both duration and leftward deviation of early superior forces. Hoffman and associates made note of the magnitude of the superior deviation of these early forces, referring to literature23 dealing with values in normal subjects obtained by other than the Frank lead system. They stated that in many of their cases of inferior infarction the superior deviation of early forces was less than 0.16 mv. Moreover, if the early vectors were deviated superiorly...
0.20 mv or more, they were always 0.025 sec or longer or 0.3 mv or more in leftward deviation. They noted that, even when the very initial 0.01-sec vector was inferior to the null point, “the rotational characteristics and duration of superior clockwise forces establish the diagnosis.”

Wolff and associates,\textsuperscript{24} using the double cube reference system of Duchosal, found the superior deviation of the early QRS forces (Qy) and the ratio of the magnitude of this deviation to that of the inferior deviation of the entire QRS (the ratio of Qy:Ry) to be diagnostically useful. No report, using the Frank reference system, has utilized both these measurements for diagnosing inferior infarction. However, Draper, and co-workers\textsuperscript{25} using the Frank system, gave values for both these parameters in normal subjects. They found that the mean of the Qy amplitude was 0.10 mv and its standard deviation was ±0.07 mv. The mean of the ratio of Qy:Ry was 0.10 and its standard deviation was ±0.05.

Hugenholtz and associates\textsuperscript{8} wrote that in the Frank reference system as well as in the cube “displacement of the same 0.025-sec vector above the 0° to the 180° axis was also found to be the most reliable evidence for inferior or apical infarction.” In addition, they pointed out that in the Frank system if the frontal plane maximal QRS vector lies above +20° (less than +20°) initial clockwise rotation in this plane is one of the most reliable signs of inferior infarction. Hugenholtz and co-workers found nine of 71 cases in which “separation from normal controls remained difficult.”

Walsh and associates\textsuperscript{9} found by the Frank system that the 0.02-sec frontal plane QRS vector was generally located inferiorly and that of old or recent inferior infarction superiorly. They noted that there was overlap of the extreme range in 15% of cases. In 85% of their series of 100 normals, the frontal plane 0.02-sec vector averaged +30°, the usual range being from +5° to +50° (quadrant 1) and the extreme range from −25° to +100° (quadrants 4, 1, or 2). In their inferior infarction series, the 0.02-sec vector averaged −80° (quadrant 4), the usual range being from −130° to 0° (quadrant 3 or 4) and the extreme range from −150° to +5° (quadrant 3, 4, or 1).

Abramson\textsuperscript{10} compared the magnitude of the 0.02-sec vector with that of the maximal QRS vector in the Frank frontal plane VCG. This ratio was found not to be greater than 0.16 in the normal heart with clockwise loop inscription and a superiorly directed 0.02-sec vector. He found that 46 of 50 patients with inferior infarctions with clockwise or figure-of-eight loop showed a superior 0.02-sec vector. All but four of these 46 had a ratio that was more than 0.16. He also noted that this rule applied even when very initial forces were inferior. Abramson also found that, assuming the loop was inscribed in a clockwise direction, the normal upper limits for the frontal plane 0.02-sec vector was −77°. In addition, none of the normal loops had the 0.02-sec vector both superior to the null point and associated with a frontal plane maximal QRS vector located above +35° (less than +35°).

**Results**

**QRS Loop of the Frontal Plane VCG**

Early superior QRS forces occurred in all 100 cases of inferior myocardial infarction and in 226 of the 315 normal control subjects. Several parameters pertaining to these early vectors were evaluated as follows (fig. 1).

**Normal**

In the 226, early superior forces were always followed by mid-to-late (not necessarily terminal) inferior and leftward vectors.

**Direction of Inscription (Rotation).** Early superior forces in the 226 cases showed either complete or almost complete counterclockwise rotation (CC), figure-of-eight configuration (S), complete or almost complete superimposition (S), complete (C) or almost complete (AC) clockwise direction of inscription (fig. 2).

In some loops the rotation of the early superior forces varied with normal respiration. In these cases the classification denoting...
the most counterclockwise direction was chosen for analysis. This change in rotation was usually only one category in a more clockwise direction, that is, from CC to 8, 8 to S, S to AC or AC to C.

In most instances it was obvious that the early superior vectors corresponded to one of the above five categories even when amplifier gain was decreased to 2.5 to 3.5-cm deflection per 1 mv of signal input. However, in order to show clearly the direction of inscription of early superior forces, amplifier gain in some cases had to be increased to as much as 9.0-cm deflection per 1 mv of signal input. In these examples the loops recorded at such increased amplifier gain settings were used for tabulating rotation.

In 17 of the 226 cases, early superior vectors were preceded by initial inferior forces. Thus, this sequence in location of initial and subsequent early vectors may occur as a normal variant and hereafter in this report, in the normal, will be referred to as the "normal variant" (see section on "Normal Variant"). One other case, differing slightly from these 17, will also be discussed in the same section.

In the other 208, all of the early vectors, including initial forces, were superior to the null point.

In 76 of these 208 normal subjects, early superior forces were inscribed in a counterclockwise direction (CC). These 76 will not be analyzed because none of the 100 inferior infarction cases had early superior forces that simulated CC rotation as herein defined (compare loops 1 to 5 in fig. 2 with loops in figs. 7 to 10). The remaining 132 cases are discussed below.

Contour (Shape). According to their contour, early superior forces in the 132 cases corresponded to one of three contours: A, B, or 8 (figs. 3 to 5).

Quantitative Scalar and Planar Measurements. In these 132 cases several other parameters, pertaining to early superior forces, in addition to their contour and direction of inscription, are analyzed in graph 1 and table 2.* Some of these parameters, both scalar and

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*To conserve space, table 2 was not printed. In addition to rotation and contour, table 2 also presents an analysis, in the 132, of all parameters discussed in the section on "Background Material." Upon request, a copy of table 2 will be sent with the reprint of this report.
FRONTAL PLANE VECTORCARDIOGRAM

planar, have been used in the past in diagnosing inferior myocardial infarction or defining the normal.7–10, 21, 23–25

Twenty-three of the 132 normal control subjects had a frontal plane maximal QRS vector above +35° (less than +35°); nine of these 23 subjects were less than 40 years of age. Six of the 23 had the frontal plane maximal QRS vectors above +25° (less than +25°); two of the six were also less than 40

![Diagram of vectorcardiogram examples]

**Figure 2**

Examples, among the normal, of the variations in direction of inscription (rotation) of early superior forces: CC = complete or almost complete counterclockwise inscription; 8 = figure-of-eight configuration with approximately equal areas enclosed by vectors to the right and left of the cross-over; S = complete or almost complete superimposition; AC = almost complete clockwise inscription with a cross-over or superimposition of vectors at the most rightward (though not necessarily to the right of the null point) portion that usually corresponded to the most superior forces as well; C = total clockwise inscription.
years old. This correlation of age with the planar location of the maximal QRS vector, even in these subjects, corresponds to the findings of others.\textsuperscript{26, 27} Frontal plane loops which lie in the horizontal position directed to the left are seen more commonly in the normal older age group than in the normal younger adult population.

Two unique but similar cases among the 132 required detailed description to separate them from the cases of infarction (see asterisk [*] in fig. 4 and graph 1).

\textit{Normal Variant.} Seventeen other normal control subjects, not among the 132, displayed the normal variant of early superior QRS forces (fig. 6 and table 3). In all 17, the relatively small initial vectors were inferior and partially or completely to the right of the null point. Moreover, in these 17, early superior forces following these initial inferior vectors were inscribed in a complete clockwise direction (C) and their contour was similar to contour B. In one other example the initial forces differed slightly from those in these 17 (loop 8 in fig. 6 and last case in table 3), but subsequent early superior vectors were similar. The frontal plane forms, that is, the maximal QRS vectors, in the 18 lie in the horizontal position directed to the left. Three

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure3.png}
\caption{Variations in contour A of early superior forces found among the group of 132 normals discussed in text (see graph 1 and table 2): In shape A the distal tip corresponded to the most superior and usually most rightward portion of these vectors. However, this point did not necessarily lie to the right of the null point (loops 2, 5, and 13).

In contour A, early superior forces were more or less linear (loops 11 to 14), their afferent and efferent limbs were narrow but separated throughout (loops 1, 4, and 5), or the relatively widely separated portion of these two limbs tapered to a well-defined apogee (loops 2, 3, and 6 to 10). After their most superior point, the early superior forces of contour A were immediately directed downward. However, their angle of descent (steepness) varied.

To contrast clearly the characteristics of contour A with contours B and 8, loops were usually photographed with amplifier gain adjusted so that 1 mV of signal equalled a deflection of 4.0 to 8.0 cm. Precautions must be taken to prevent artificial movements of the trace due to exaggerated respirations from distorting contour.

Note that some of these contour A normal loops fulfilled one or more criteria currently in use\textsuperscript{7, 8} for the diagnosis of inferior infarction.}
\end{figure}
Variations in contour B of early superior forces found among the group of 132 normals discussed in text (see graph 1 and table 2). All 11 instances of contour B, found among the 132 normals, are illustrated: In contour B early superior forces formed an upward convexity that was located more leftward than the initial superior forces. This convexity did not necessarily lie entirely to the left of the null point (loops 3 and 5 to 7). Early vectors, after reaching their most superior position, remained at this elevation for a variable time rather than immediately descending as in shape A.

Loops 1* and 2* (those of females, aged 26 and 39 years) were unique among the entire normal series. In these two, early superior forces, hardly to the right and superior to the null point, showed a cross-over or superimposition at their most rightward portion. These early superior vectors were then momentarily directed downward before ascending and deviating markedly to the left in a clockwise direction. Although early superior forces in both cases fulfilled two criteria now in use for the diagnosis of inferior myocardial infarction,7,8 their overall pattern differed from that of the 100 cases of inferior infarctions to be presented (compare with figs. 8 to 10).

However, in the other nine cases, neither of these two criteria7,8 was satisfied.

Variations in contour 8 of early superior forces found among the group of 132 normals discussed in text (see graph 1 and table 2): In shape 8, the most superior portion of early forces was rounded and at least part of the subsequent downwardly directed superior vectors was more rightward than the most superior early forces. Note that this contour also corresponded to 8 in rotation.
Graph 1
Interrelationships of several parameters pertaining to the early forces in the 132 normals whose early vectors including the initial forces were superior to the null point (see text and table 2). Duration in milliseconds = ordinate; leftward deviation in millivolts = abcissa.
(Continued on page 613)
of the 18 subjects were less than 40 years of age.

Many cases among the 18 fulfilled criteria\textsuperscript{7,8,10} currently in use for the diagnosis of inferior infarction. Seven of these normal cases satisfied one such criterion.\textsuperscript{8} This criterion states that early superior forces are diagnostic if they are clockwise and are associated with a maximal QRS vector above $+20^\circ$ (less than $+20^\circ$) even when their duration is less than 0.025 sec. In addition, eight cases fulfilled another criterion.\textsuperscript{7} This states that early superior forces are diagnostic if they show a leftward deviation of 0.3 mv or more even if their duration is less than 0.025 sec.

Some reports\textsuperscript{8,10} have utilized the location of an instantaneous vector as a criterion for diagnosing inferior infarction.

One reason for misjudging the diagnostic importance of the position of the 0.025-sec vector, if it is superior to the null point, is demonstrated in six of the aforementioned 18 cases. In these six the 0.025-sec vector, timed from the onset of the QRS to include these initial inferior forces, was superior. However, the total duration of the early superior vectors was less than 0.02 sec in all these examples.

In addition, if the 0.02-sec vector was similarly timed from the onset of QRS, seven examples would have fulfilled another criterion.\textsuperscript{10} This criterion is satisfied, provided there is clockwise inscription of the loop and a superiorly directed 0.02-sec vector, when

the ratio of the magnitude of the 0.02-sec vector to that of the maximal vector is greater than 0.16.

\textit{Old Inferior Infarction}

In 94 of the 100 cases of old inferior infarction, early superior forces were followed by mid-to-late (not necessarily terminal) inferior and leftward vectors. In the other six cases all of the leftward forces were superior to the null point (fig. 7).

\textit{Direction of Inscription (Rotation).} According to their direction of inscription early superior forces, as herein defined, showed complete clockwise inscription in 94 cases (figs. 7, 8, 10, and 11) and almost complete clockwise rotation (AC) in the other six (fig. 9). (See section on “Normal” for definitions of C and AC rotation.)

In 11 cases early superior vectors were preceded by initial inferior forces. These 11 will be analyzed, in detail, in the section on “Initial Inferior Forces in Old Inferior Infarction.” In the remaining 89, all of the early forces, including initial vectors, were above the null point.

\textit{Contour (Shape).} The contour of the early superior forces corresponded to shape A in six cases (fig. 10 and graph 2) and to shape B in the other 83 of these 89 cases (figs. 7 to 9, and graph 2).

\textit{Quantitative Scalar and Planar Measurements.} In these 89 cases several other parameters of early superior forces, in addition

\begin{center}
\textbf{The following symbols indicate direction of inscription (rotation) as defined in figure 2:}\\
\(\Delta = S; \; \alpha = 8; \; \circ =\text{AC}; \; \bullet = C.\)
\end{center}

\begin{itemize}
  \item In nine cases, early superior vectors, varying with normal respiration, showed either AC or C rotation. These nine cases are represented by symbol \(\circ.\)
  \item Contour B (less common than contour A in the 132) is indicated by a vertical bar above the rotation symbol, that is, \(\circ.\) contour A has no bar above the rotation symbol, that is, \(\circ\) (see figs. 3 and 4 for definition of contours A and B).
  \item The \(F^*\) of the maximal QRS vector is noted next to the rotation symbol. In the 132 the planar location of this vector was always \(+,\) that is, inferior to the null point. If the 0.02-sec vector was superior, the planar location of this instantaneous vector is shown by a negative value above the number indicating \(F^*\) of the maximal QRS vector. Two unique cases (see also fig. 4) are indicated by an asterisk (*).
  \item Note that many cases among these 132 fulfilled one or more of the criteria now in use\textsuperscript{7--10} for diagnosing inferior infarction.
\end{itemize}
Examples of early superior vectors from among the 18 normal subjects, displaying the normal variant (see table 3 also). Note that rotation abbreviations refer to the direction of inscription of initial inferior vectors. In all 18, the subsequent early superior forces were inscribed in a total clockwise direction (C) and their contour corresponded to contour B. Duration in seconds of initial inferior forces is indicated by ▼, that of subsequent early superior vectors by ▲.

In one unique case (loop 8—same case as last example in table 3) the earliest part of the QRS was superior and counterclockwise in all cycles; its duration is indicated by ▲. However, the subsequent part of initial vectors was inferior and its duration is indicated by ▼.

In five cases the earliest part of inferior vectors, varying with normal respiration, became displaced above the null point in some cycles (illustrated by loops 1 and 2).

Although in all 18 the beginning of initial inferior forces lay to the right of the null point, in some the latter part of these forces was inferior and to the left (loops 4, 6, and 8).

In some loops the direction of inscription of initial inferior vectors varied with normal respiration (loops 3 and 4).
to contour and direction of inscription, are analyzed in graph 2 and table 4.*

Initial Inferior Forces in Old Inferior Infarction. In 11 cases, in contrast to the 89, the initial vectors were inferior to the null point, (figs. 7, 9, and 11, and table 5). In these 11, early superior forces following the initial inferior vectors were completely clockwise with one exception. The contour in all 11 corresponded to shape B.

VCG Differential Diagnosis of Old Inferior Myocardial Infarction Versus Normal Controls (Frontal Plane Early QRS Vectors)

VCGs were divided into two groups: In group 1, all of the early forces, including initial vectors, were superior to the null point.

Table 3

Analysis of the Eighteen Cases Displaying the Normal Variant of Early Superior Forces; See Figure 6 Also

<table>
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<tr>
<th>F* of maximal QRS</th>
<th>Duration (sec)</th>
<th>Inferior (mv)</th>
<th>Rotation</th>
<th>Duration (sec)</th>
<th>Superior (mv)</th>
<th>Left (mv)</th>
<th>Max. QRS</th>
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<tbody>
<tr>
<td>+10</td>
<td>0.01</td>
<td>0.02</td>
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<td>0.0125</td>
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<td>0.25</td>
<td>—</td>
</tr>
<tr>
<td>+15</td>
<td>0.012</td>
<td>0.02</td>
<td>CC</td>
<td>0.006</td>
<td>0.02</td>
<td>0.25</td>
<td>—</td>
</tr>
<tr>
<td>+45</td>
<td>0.012</td>
<td>0.03</td>
<td>CC-S</td>
<td>0.006</td>
<td>0.03</td>
<td>0.14</td>
<td>—</td>
</tr>
<tr>
<td>+30</td>
<td>0.012</td>
<td>0.04</td>
<td>C</td>
<td>0.014</td>
<td>0.10</td>
<td>0.30</td>
<td>0.08</td>
</tr>
<tr>
<td>+20</td>
<td>0.0075</td>
<td>0.02</td>
<td>C</td>
<td>0.0125</td>
<td>0.04</td>
<td>0.030</td>
<td>0.22</td>
</tr>
<tr>
<td>+25</td>
<td>0.0075</td>
<td>0.02</td>
<td>C</td>
<td>0.01</td>
<td>0.05</td>
<td>0.13</td>
<td>—</td>
</tr>
<tr>
<td>+15</td>
<td>0.007</td>
<td>0.01</td>
<td>CC↑</td>
<td>0.009</td>
<td>0.04</td>
<td>0.55</td>
<td>0.36</td>
</tr>
<tr>
<td>+10</td>
<td>0.010</td>
<td></td>
<td>CC↓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Explanation: In the normal variant the initial vectors were inferior and are tabulated according to duration (both to the right and left of the null point) in column 2, inferior deviation is tabulated in column 3, and rotation, in column 4. In some cases rotation of the initial inferior forces varied, as noted in column 4, with normal respiration. In five instances, varying with normal respiration, the earliest part of inferior vectors deviated slightly above the null point in some cardiac cycles. This cyclic superior displacement in inferior forces (indicated by ↑) was also associated with a change in rotation of these vectors (shown by rotation symbol) in column 4. The last case (same case as loop 8 of fig. 6) differed from the other 17 because the onset of the QRS was superior and inscribed in a counterclockwise direction in all cycles. However, the subsequent vectors were inferior to the null point. The early superior forces (columns 5 to 8) that followed these inferior forces in all 18 cases were inscribed in an entirely counterclockwise direction (C) and their contour corresponded to B. The ratio of the magnitude of the early 0.02-sec vector, if it is above the null point when timed from the onset of QRS, to that of the frontal plane maximal QRS vector is shown in column 8.

Note that many of these cases fulfilled one or more criteria now in use7, 8, 10 for diagnosing inferior infarction.
Complete QRS loops in the six cases of inferior infarction in which leftward forces were entirely superior to the null point. The basic standard of 1x equals 1.8-cm deflection per 1 mv of signal input. (All loops are half original size.)

In all forms, except loop 4, superior vectors of the efferent limb up to their maximal leftward point were considered as the early superior forces. (In the normal, this maximal leftward point was usually followed by mid-to-late inferior leftward forces.) Loop 4 differed from the loops in the other five cases because the latter part of its efferent limb became counterclockwise. For the sake of simplicity in reporting results, superior vectors of the efferent limb up to this point of reversal in rotation (indicated by timing bar) were analyzed as the early superior forces.

(1) In the other 94 cases of infarction, all the superior forces that preceded the inferior leftward vectors were analyzed as the early superior forces.

(2) In all loops, except loop 4, the entire efferent limb of early superior forces was considered as being completely clockwise (C). In loop 4, early superior forces, as defined above, were also analyzed as being completely clockwise. Some investigators would have described the entire efferent limb of the superior vectors in forms 1, 2, 4, and 5 as counterclockwise. However, these vectors were considered to be clockwise because they were directed markedly to the left (compare with loops 1 to 5 of fig. 2).

In loops 1, 3, and 4 initial vectors were inferior and to the right of the null point as well as clockwise in direction. In loops 1, 2, 4, and 5 the afferent limb

In group 2 early superior forces were preceded by initial inferior vectors.

For the differential diagnosis of group 1 loops, compare graph 1 (normal subjects) with graph 2 (infarction cases). For the differential diagnosis of group 2 loops, compare table 3 (normal subjects) with table 5 (patients with infarction).

**VCG Criteria for the Diagnosis of Old Inferior Myocardial Infarction**

As the result of the above comparative analysis and in order to prevent any overlap, the following frontal plane criteria are proposed.

Group 1

1. Early superior forces must be completely clockwise in rotation (C), contour B in shape, 0.02-sec or more in duration, and more than 0.25 mv in leftward deviation.

2. In some unusual cases of inferior and associated anterior infarction, criterion 1 applies even if early superior forces are almost completely clockwise in rotation (AC). However, in these cases, early superior vectors must be 0.025 sec or longer.

3. Completely clockwise early superior vectors, regardless of their contour, duration, or the magnitude of their leftward deviation, are diagnostic provided they are associated with a maximal QRS vector above +10° (less than +10°).

Group 2

4. Criterion 1 applies only if the preceding initial inferior forces are to the right and completely clockwise. Moreover, in these cases, subsequent early superior forces must be 0.025 sec or longer and must also fulfill the other requirements listed under criterion 1. (The analysis of this group suggests that if the maximal QRS vector lies above +10° (less than +10°) the early superior forces may be less than 0.025 sec in duration, or

of superior forces was counterclockwise. In all six cases, early superior forces, as herein defined, showed a distinct upward convexity and thus were considered to correspond to contour B.
Examples, among the inferior infarctions, of complete clockwise early superior vectors. In all forms, except loop 7, only the early superior forces are illustrated. In loop 7 the entire QRS loop is shown; the vectors below the timing bar were inferior to the null point: In loop 7 the afferent limb of the mid-to-late QRS vector, mostly superiorly located, was partly superimposed upon the efferent limb of early superior forces which were directed completely clockwise. In all 11 forms the contour of these early superior forces corresponded to shape B. In loop 11 the most superior portion of early forces showed a localized “pointing” that was located well to the left of initial rightward, superior vector (contrast with normal loops in fig. 3). Aside from this localized deformity the overall shape of early superior forces showed an upward convexity and thus were defined as being contour B. This case was the only one among the 100 cases of infarction that showed this unusual type of pointed deformity. In some loops as in 3, 5, and 7, there were “bumps” in the contour of early superior forces. Nevertheless, their shape was considered to correspond to contour B because their overall pattern displayed an upward convexity. See all loops in figures 7 and 11 and loops 1, 2, and 3 in figure 10 for other examples of completely clockwise early superior forces in inferior infarction. (See figure 7 for the definition and description of completely clockwise early superior forces in loops of inferior infarction whose leftward vectors were all above the null point.)

In contrast to the normal (see text and graph 1) the direction of inscription of early superior forces in inferior infarction that showed complete clockwise rotation remained stable irrespective of respiration.
Figure 9
Variations, among the 100 inferior infarctions, in the pattern of almost completely clockwise (AC) directed early superior forces. AC “rotation” was found in only six cases among the entire infarction series (see legend for fig. 2 for definition of AC “rotation”). Although loops 1 and 5 showed superimposition of a well-defined portion of the most rightward early superior forces, most of the early superior vectors were completely clockwise. The AC rotation of these six loops should not be confused with that of some normals whose early vectors were more or less completely superimposed (S) or figure-of-eight in configuration (8) (see fig. 2). Loops 1, 3, and 4 were associated with an “electrically pure” inferior infarction whereas loops 2, 5, and 6 were associated with anterior as well as inferior infarction. In all loops but loop 6 the small area of superimposition or figure-of-eight configuration occurred at the extreme rightward portion of early superior forces. In loop 5 initial forces were inferior and to the left of the null point as well as counterclockwise in direction. Early superior forces in loops 1, 5, and 6 corresponded to contour B and those in loops 3 and 4 simulated contour A (see legend of fig. 3 for definition of contour A). In loop 2 the initial portion of early superior vectors corresponded to contour A but the latter part was similar to contour B (* in graph 2).

Figure 10
Variations, among the inferior infarctions, in contour A early superior forces. The six cases with contour A vectors, found among the 100, are illustrated: Although the initial superior vectors in loop 4 showed an A shape, the latter part of early superior forces corresponded to contour B (* in graph 2). Note that loops 1 to 3 were also completely clockwise but did not fulfill two criteria for the diagnosis of inferior infarction, that is, duration of 0.025 sec or longer or leftward deviation of 0.3 mv or more.7,8 In five cases there were “electrically pure” inferior infarctions. Loop 4 was associated with anterior as well as inferior infarction.
FRONTAL PLANE VECTORCARDIOGRAM

Table 5

Analysis of the Eleven Cases of Old Inferior Infarction in Which the Early Superior Forces Were Preceded by Initial Inferior Forces*

<table>
<thead>
<tr>
<th>F* of maximal QRS</th>
<th>Initial inferior vectors</th>
<th>Early superior forces</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Duration (sec)</td>
<td>Inferior (mv)</td>
</tr>
<tr>
<td>-15</td>
<td>0.0075</td>
<td>0.03</td>
</tr>
<tr>
<td>+10</td>
<td>0.008</td>
<td>0.02</td>
</tr>
<tr>
<td>0</td>
<td>0.01</td>
<td>0.03</td>
</tr>
<tr>
<td>+5</td>
<td>0.01</td>
<td>0.02</td>
</tr>
<tr>
<td>-15</td>
<td>0.01</td>
<td>0.04</td>
</tr>
<tr>
<td>+12</td>
<td>0.008</td>
<td>0.02</td>
</tr>
<tr>
<td>+35</td>
<td>0.008</td>
<td>0.03 (Left)</td>
</tr>
<tr>
<td>-5</td>
<td>0.013</td>
<td>0.03</td>
</tr>
<tr>
<td>-8</td>
<td>0.006</td>
<td>0.02</td>
</tr>
<tr>
<td>+30</td>
<td>0.01</td>
<td>0.02 (Left)</td>
</tr>
<tr>
<td>+10</td>
<td>0.008</td>
<td>0.01</td>
</tr>
</tbody>
</table>

*See loops 1, 3, and 4 of figure 7, loop 5 of figure 9, and all loops of figure 11.

Explanation: In these 11 cases the initial vectors were inferior and are tabulated according to their total duration in column 2, inferior deviation in column 3, and rotation in column 4. In the seventh and tenth cases in the table (same cases as loop 5 of fig. 9 and loop 5 of fig. 11, respectively) initial inferior forces were entirely leftward; both these examples were associated with anterior as well as inferior infarction. In all but one other case, among the 11, the initial inferior vectors were to the right and entirely clockwise directed. In this other example (last case in this table, same case as loops 7 and 8 in fig. 11) the initial inferior forces were to the right and clockwise in some cycles but counterclockwise and partially to the left in other cycles, varying with normal respiration. The early superior forces (columns 5 to 8) that followed these initial inferior forces in all but one example among these 11 (case 7 of this table, marked AC, same case as loop 5 of fig. 9) were entirely clockwise and their contour in all 11 cases corresponded to group B. Column 8 shows the ratio of the magnitude of the early 0.02-sec vector, if it is above the null point when timed from the onset of the QRS, to that of the frontal plane maximal QRS vector.

less than 0.25 mv in leftward deviation or both.)

5. In some unusual cases of inferior and associated anterior infarction, criterion 4 may be modified as follows: (a) Initial inferior forces may be to the left and counterclockwise or superimposed, or both. (b) The subsequent early superior forces may be almost completely clockwise.

A comparison of table 2 (normals) with table 4 (infarctions) and table 3 (normals) with table 5 (infarctions) shows that the use of only scalar or planar criteria results in a large number of false positive or false negative diagnoses of inferior infarction.

ECG Correlation

The ECG made at time of VCG was classified according to whether lead aVF showed: (1) an initial Q wave, (2) an initial R wave, or (3) a Q-S deflection.

Eighty-four patients displayed an initial Q followed by an R wave in lead aVF. Only 40 of these cases fulfilled either the Myers and associates' or the Goldberger's classical QRS criteria for the diagnosis of inferior infarction or both. However, 77 of the 84 fulfilled one or more of the five VCG criteria proposed.

Eleven patients had a Q-S in aVF. Thus these 11 did not fulfill the criteria of Myers and associates' or Goldberger. However, two of these also had a Q-S in lead II, and therefore, the diagnosis was thought to be correct. In contrast 10 of the 11 cases fulfilled one or more of the VCG criteria.

Five patients had an R/S in aVF. Four of these five also had an R/S in lead II. The other patient had a small upright QRS in this lead. Thus, these five could not be diagnosed from the ECG.

All 42 cases diagnosed from the ECG also satisfied one or more of the VCG criteria.

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Graph 2

Analyses of the early superior forces in 89 of the 100 cases of inferior infarctions. In these 89 all of the early vectors, including the initial forces, were superior to the null point. Duration in milliseconds is plotted on the ordinate, leftward deviation in millivolts on the abscissa. The following symbols indicate direction of inscription: \( \bullet = C \) and \( o = AC \). Five cases among the 89 showed AC rotation; two of these, one with a duration of early superior forces of 0.038 and the other 0.040 sec, were associated with anterior as well as inferior infarction. Contour that is, \( \bullet \); contour B has no bar above rotation symbol, that is, \( o \). In * the initial portion of early A (less common than contour B in the 89) is indicated by a vertical bar above rotation symbol.
Graph 2 (continued)

superior vectors displayed an A contour, but the latter part of early superior vectors had a B shape (same case as loop 2 in fig. 9 and loop 4 in fig. 10). Note that in graph 1 (normal subjects), in contrast to graph (patients with infarction), contour B (the unusual shape of normal early superior forces) was shown by a vertical bar above rotation symbol and contour A had no bar above rotation symbol. In the 89 infarctions, the $F^o$ of maximal QRS vector is noted next to rotation symbol. If the early 0.02-sec vector was superior to the null point, the planar location of this instantaneous vector is indicated as a negative value above the $F^o$ of the maximal QRS vector.
Eleven cases of infarction displayed early superior vectors that were preceded by initial inferior forces. Seven of these cases are shown in Figure 11. The four other examples are shown in loops 1, 3, and 4 of Figure 7 and loop 5 of Figure 9. In two of the 11 (loop 5 of Fig. 9 and loop 5 of Fig. 11) initial inferior vectors were entirely leftward and counterclockwise in the first example and superimposed in the second. Both these cases were associated with anterior as well as inferior infarction. Note that in all other cases, except loop 8 of Figure 11, initial inferior forces were to the right of the null point and entirely clockwise directed. In loop 8 (same case as loop 7 of Fig. 11 and case 11 of Table 5) the initial inferior forces were to the right and clockwise in some cycles but counterclockwise and partially to the left in others, varying with normal respiration. The early superior vectors that followed these initial inferior forces in all but one example among the 11 (loop 5 of Fig. 9) were entirely clockwise and their contour in all 11 corresponded to contour B.

Discussion

The importance of total pattern analysis of the early part of QRS in the frontal plane VCG of an old inferior infarction has been stressed in this report. Pitfalls in the use of only planar or scalar parameters in the frontal plane VCG and lead aVF have been pointed out.

The total pattern approach to interpreting VCGs is not limited to the early part of QRS but applies to mid-to-late QRS forces as well and is a useful diagnostic tool in other kinds of infarction and other cardiac abnormalities.

Addendum

Some of the VCG criteria herein proposed or currently being used for diagnosing inferior infarction may occasionally be fulfilled by other cardiac abnormalities. This same overlap occurs with the use of classical ECG criteria. Nevertheless, distinctive alterations in the mid-to-late part of the QRS-segment loop are often present in inferior infarction and may even occur when early superior QRS vectors are not diagnostic. A manuscript is now in preparation describing these changes.

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References
The Frontal Plane Vectorcardiogram in Old Inferior Myocardial Infarction: Criteria for Diagnosis and Electrocardiographic Correlation

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